

Wind Power in Newfoundland and Labrador



Canada-Newfoundland Conservation and Renewable Energy Demonstration Agreement

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Wind Power in Newfoundland and Labrador

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Canada-Newfoundland Conservation and Renewable Energy Demonstration Agreement

Our sun, wind, water and forests hold infinite energy - renewable energy - which can be harnessed for use in our industries, offices and homes. The steadily rising prices of oil and gas and the uncertainty of these fuel supplies make it profitable, even necessary, to tap our renewable resources. Yet energy savings only start here. Conservation techniques, working together with renewable energy technologies, mean further reductions in our conventional energy requirements.

Until recently, the economic and technical feasibility of many of the innovative energy techniques and technologies had not been thoroughly tested in Newfoundland and Labrador, nor in many other regions of Canada. The conditions existed for successful application of energy products and techniques. To encourage new developments and demonstrations, the federal and provincial energy departments agreed on a conservation and renewable energy agreement for each province and territory of the country.

Newfoundland's program was implemented under the **Canada - Newfoundland Conservation and Renewable Energy Demonstration Agreement (CREDA)**. The agreement, signed in June 1979, provided up to \$11,250,000 over a six-year period for energy projects approved under the program. Canada's share of the costs amounted to 80 percent of the total cost and Newfoundland's share was 20 percent of the total.

The end goal of this development and demonstration program is to encourage successful application of innovative technologies. The data from these projects has been collected and information on performance and cost of the various energy systems in this province is now available.

This book presents a summary of the information available on just one of our renewable resources.

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Introduction

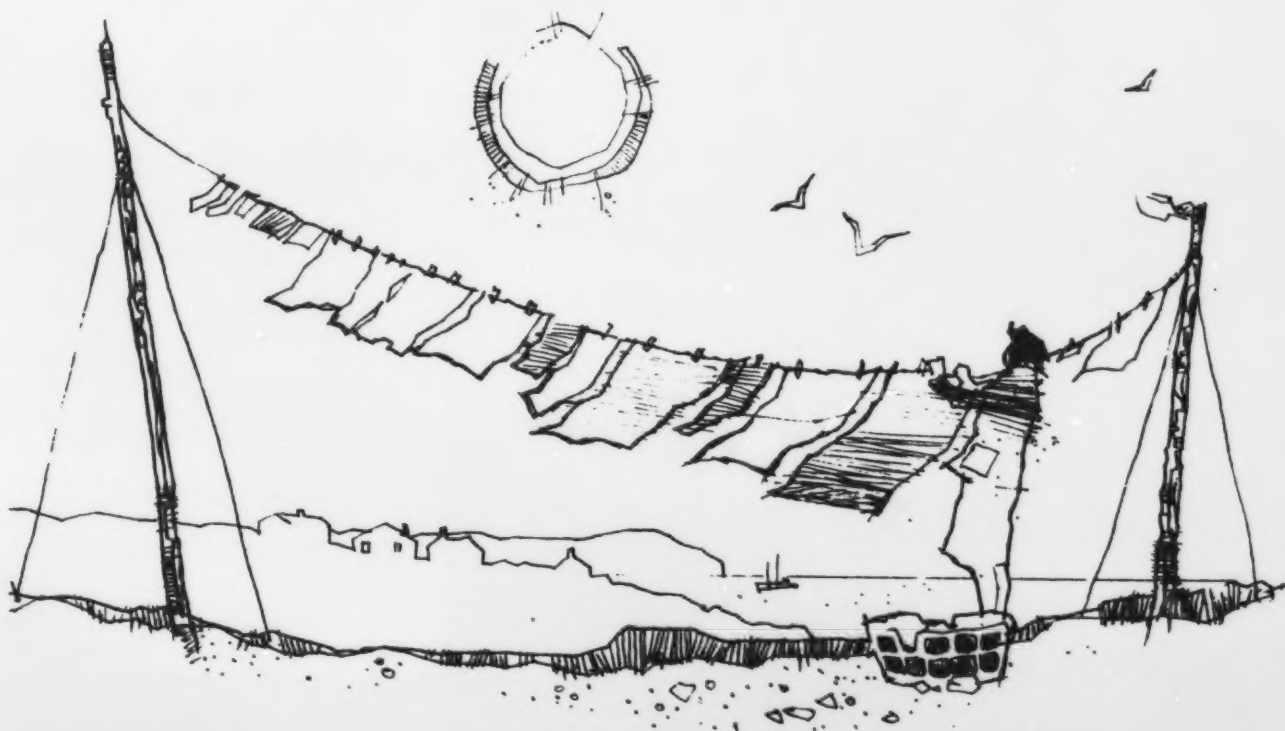
Newfoundland is 'blessed' with a windy climate. In the days of the schooner, before diesel engines, wind provided the energy for transportation and travel; it carried men to the fishing grounds and brought them and their haul safely home again. Today sailing vessels are used mostly for pleasure, but there are other ways to put the wind to work for you. Using modern technology to harness the wind, you can generate electricity, produce heat or pump water with a variety of reliable small scale wind turbines.

At a cost of around \$10,000 for a 2 kilowatt system, these turbines are expensive to purchase and install. But for those people who live away from the power grid or who pay a high price for diesel generated electricity, wind turbines can be an economical source of energy.

Wind energy systems are normally manufactured but they can be built at home. In either case they must be high quality, sturdy machines to stand the test of time.

This book explains the basic principles of wind generated electricity. At the back of the book are a number of technical profiles for residential wind-turbine projects completed in this province.

Further information can be obtained from the references and suppliers listed at the back of this book.

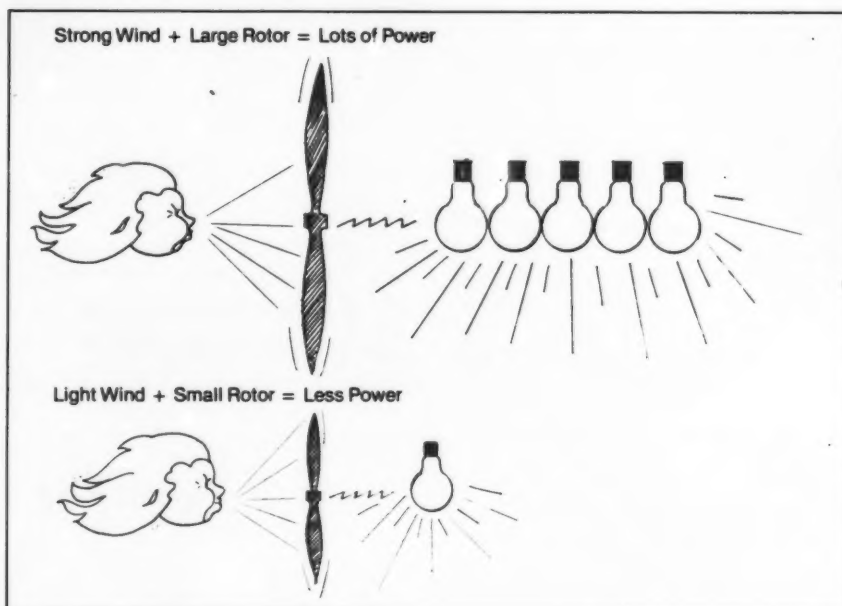


Power from the Wind

How does the wind produce power? Its forward motion turns something, for example, a wind turbine. The rotation of the wind turbine shaft can be used to produce mechanical or electrical power.

The power output depends on the area swept by the rotors, the efficiency of the system and the windspeed.

The longer the rotors and the stronger the wind, the more of the wind's forward energy will be transformed into rotational energy. These important factors are discussed in the following sections, with examples of how they can be calculated.



The equation relating these factors is

$$\begin{aligned} \text{Power} \\ \text{produced} = & 0.01319 \\ & \times \text{Area} \\ & \times (\text{Windspeed})^3 \\ & \times \text{Efficiency} \end{aligned}$$

where

Power is in watts (W)

0.01319 is a constant

Area is in square metres (m²)

Windspeed is in

kilometres per hour (km/h)

Efficiency is expressed as a decimal percent

(and is always less than 1).

A quick estimate of output can be obtained from the diagram at left.

Area

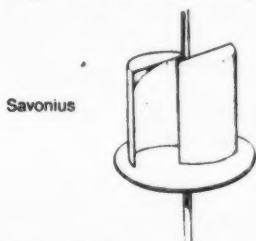
Wind turbine rotors usually sweep in a circle. If the blade diameter is 4 m, the area swept is $\pi / 4 \times (4)^2$, or 12.6 m². ($\pi = 3.14$)

For turbines with rotors that do not sweep in circles, such as vertical axis turbines, manufacturers can supply the areas.

Efficiency

Wind turbines come in a variety of types, with different efficiencies. The maximum theoretical amount of energy that can be extracted by a wind turbine is just under 60%, because a portion of the wind must keep moving through the rotor. Efficiency is further reduced by losses in the equipment.

Vertical Axis (Shaft turns vertically)



Savonius

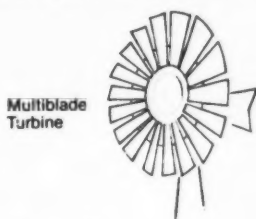
Efficiency: 16%



Darrieus

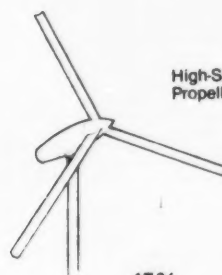
32%

Horizontal Axis (Shaft turns horizontally)



Multiblade
Turbine

Efficiency: 30%



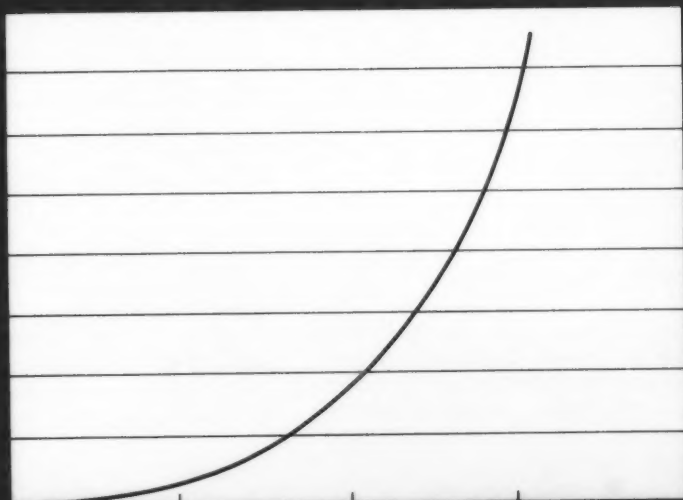
High-Speed
Propeller

45%

Windspeed

The windspeed is the most important factor in calculating power, since power is proportional to the cube of the velocity. Doubling the windspeed produces 8 times the power. Doubling the area or doubling the efficiency only doubles the power.

A complete calculation of power including area, windspeed and efficiency, is given below.



Estimating Power and Energy Needs

The amount of power and energy required from a wind turbine depends on how it will be used. This section gives an example for one typical home, but the calculations can be adjusted for other situations.

The turbine size will be based on these power and energy requirements. The required battery capacity also depends on energy consumption, as described in the next section.



Estimating Battery Storage Requirements

If the system is installed away from power lines, batteries are usually used to provide power in times of low winds. The required capacity of the battery depends on such factors as the longest expected period of low winds, how much power the wind turbine generates in the lower wind ranges, energy consumption in the home and how essential the power is to the homeowner. In most locations in Newfoundland and Labrador, the months with the lowest windspeed are July and August; fortunately in these months it is often possible to reduce energy use so that the power stored in the batteries will last longer.

Consider the previous example, in which the average energy consumption was 350 kWh per month, or 11.3 kWh per day (11 300 watt-hours per day). Assume that after considering the expected windspeed conditions and the family's needs, it was decided that a 3 day backup is required.

Battery capacity is usually expressed in ampere-hours. To convert the required energy storage from kilowatt-hours to storage capacity in ampere-hours, the following formula is used.

$$\text{Storage Capacity} = \frac{\text{Energy}}{\text{Voltage}}$$

In the example, the voltage is 120 V. For 3 days of backup,

$$\begin{aligned} \text{Required Capacity} &= \frac{11\,300 \text{ Wh/day} \times 3 \text{ days}}{120 \text{ V}} \\ &= 282.5 \text{ ampere-hours (Ah).} \end{aligned}$$

Battery systems frequently use lower voltages, e.g. 12 V, 24 V, or 32 V. Assuming the same energy of 11 300 Wh/day is to be stored in a 12 V system,

$$\begin{aligned} \text{Required Capacity} &= \frac{11\,300 \text{ Wh/day} \times 3 \text{ days}}{12 \text{ V}} \\ &= 2825 \text{ Ah.} \end{aligned}$$

This is a very large capacity, about 30 times the capacity of an ordinary 12 V car battery, for example. Both the 282.5 Ah/120 V system and the 2825 Ah/12 V system are the same size and cost; the difference between them is how they are connected. They are both very large and expensive. Two 12 V forklift batteries with 1500 Ah each would have this capacity; they cost over \$8000 each and weigh about 650 kg each.

Most homeowners find that such a large battery storage system is not worth the expense. The only way to reduce the cost is to reduce energy use during periods of low wind.

Continuing the example above, assume a 12 V DC system is chosen,

rather than 120 V DC. Low power DC appliances are used, and the number of hours the appliances are turned on is reduced when winds are low.

The average energy use per day could then be reduced to perhaps about 1000 Wh/day, and the resulting required capacity for 3 days to about 250 Ah. Batteries with this capacity for a 12 V system are readily available for about \$1500, and weigh about 150 kg.

Note that the 12 V DC appliances assumed for the above example are often rated by current in amperes; for example, a catalogue will advertise a 12 V DC washer that draws a current of 15 amps. To convert from current in

amperes to power in watts, use the formula

$$\text{Power} = \text{Voltage} \times \text{Current}$$

$$1 \text{ watt} = 1 \text{ volt} \times 1 \text{ ampere}$$

e.g. For a 15 A washer in a 12 V system, the power required is

$$15 \text{ A} \times 12 \text{ V} = 180 \text{ W}$$

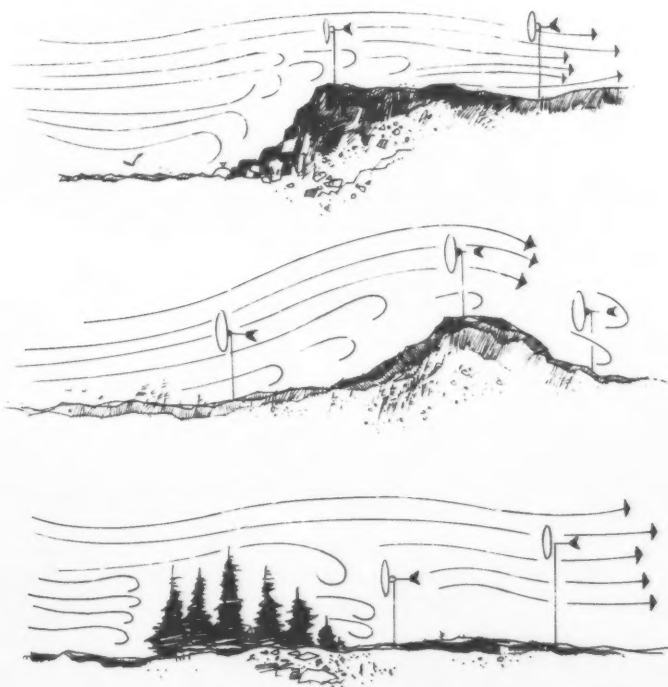
The question of what type of system to choose can be quite complicated, and will depend on the particular case. Wind turbine manufacturers and battery system suppliers can both offer advice.

Estimating Available Wind

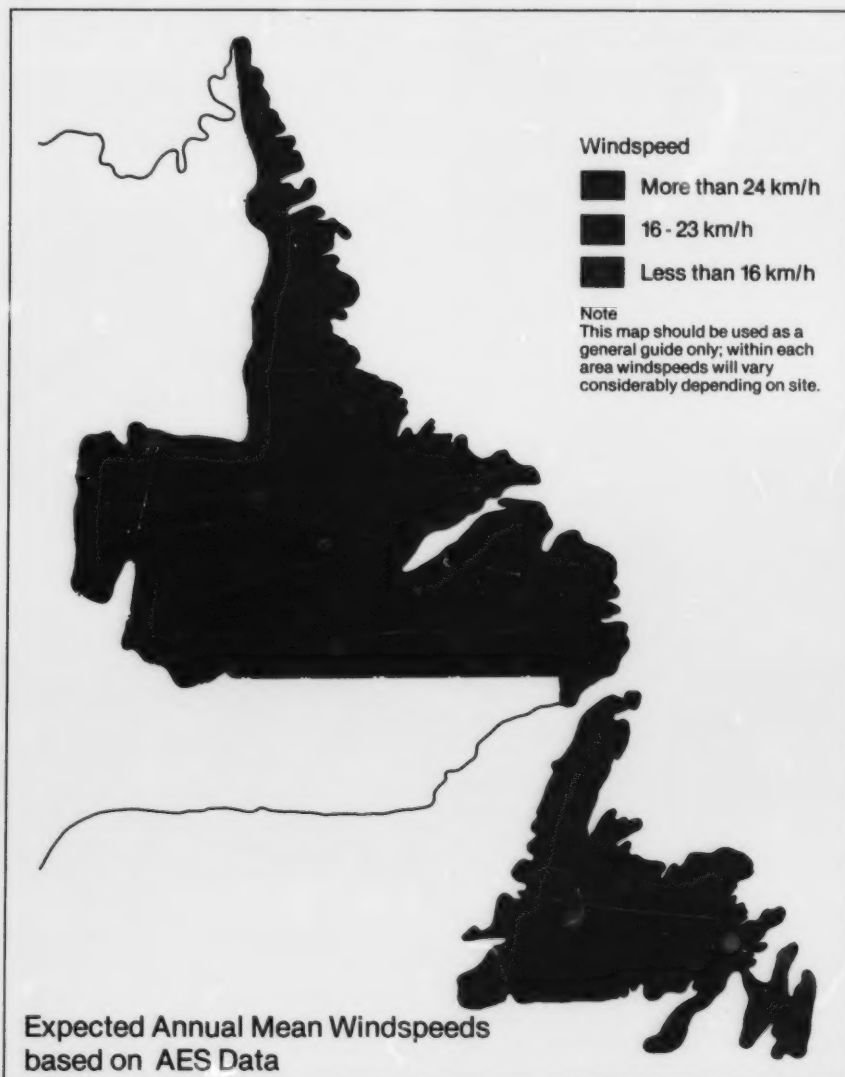
The section on power clearly showed that the windier a site is the better. A good location is chosen by first selecting a region which is generally windy and then finding the windiest spot within that region.

Newfoundland and Labrador is generally windier than most of the rest of Canada. In fact, except for a few areas like Cape Horn, Antarctica and parts of Greenland, it has as much as or more available wind energy than anywhere in the world.

The wind map of the province on page 10 gives an indication of the windier areas within the province, based on the average annual windspeeds for the Atmospheric Environment Service (AES) stations in Newfoundland and Labrador. The diagram at right shows examples of good and bad sites.



High exposed locations with smooth approaches are best. Avoid eddies.



The highest average annual windspeed recorded at AES stations is 28 km/h at Bonavista. The anemometer (windspeed recording device) is situated on an ideal site to get high winds. It is on a 10 m tower located on a small ridge 27 m above sea level. The surrounding area is relatively flat and barren. The site is exposed to the Atlantic Ocean in all quadrants except from the southwest, where the terrain rises gradually. If the tower were higher, the recorded wind would be even higher.

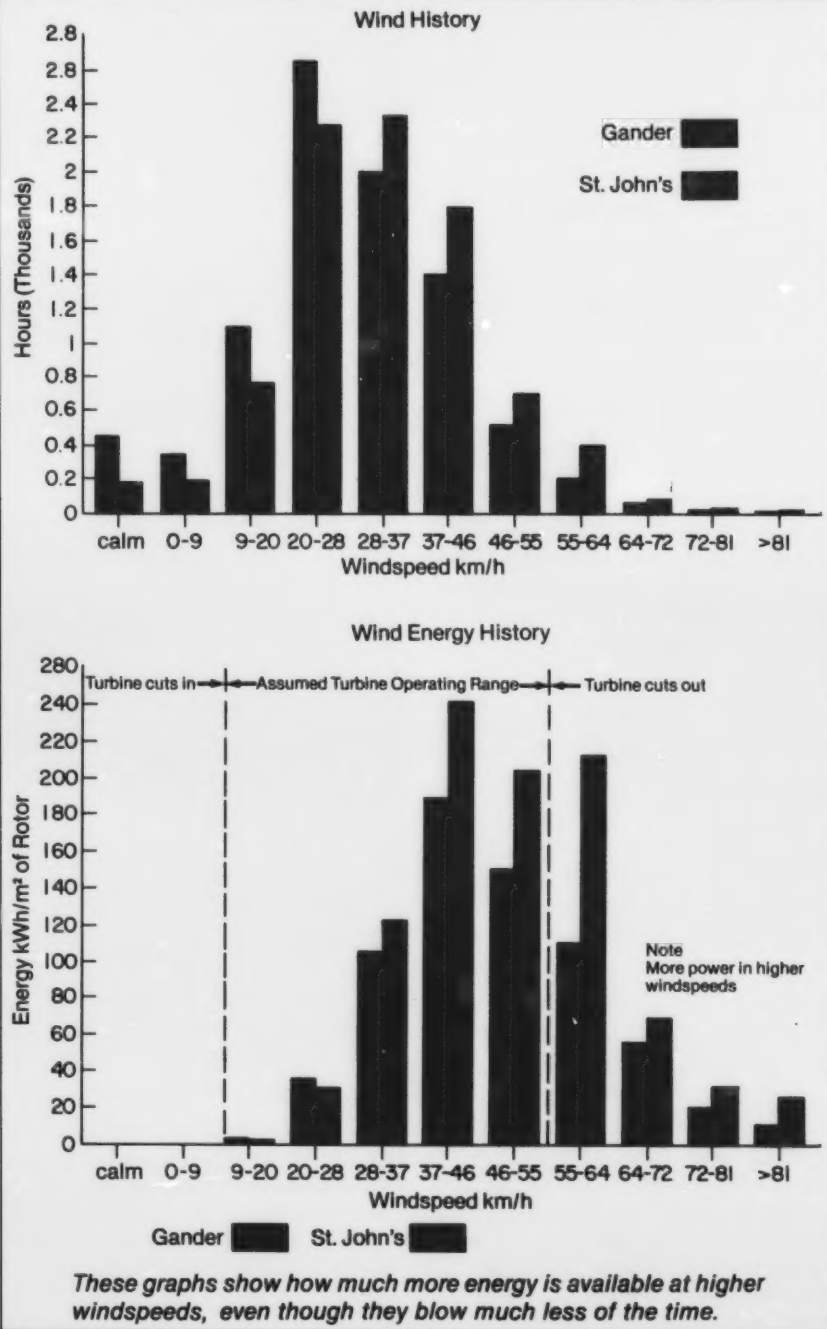
The only way to determine the expected windspeed at a site is to record it, preferably over several months. Anemometers are available from some wind machine suppliers and from meteorological equipment manufacturers.

Estimating Available Energy

Once the windspeeds have been recorded, a chart showing windspeed history can be prepared. An example is shown using the recorded windspeeds from St. John's and Gander Airports.

From these windspeeds, a wind energy history can be drawn. This shows how many kWh of energy can be expected for each square metre of swept area in each range of windspeeds. An average efficiency must be assumed.

From this wind energy history, the required size of rotors can be determined to meet a particular set of energy needs.



energy in the St. John's area because it is windier.

These calculations are simplified, and do not show the appreciable

variation in windspeed from month to month. They do show in principle how available wind energy is matched to energy needs to select an appropriate turbine.

A similar calculation shows that a smaller rotor would provide the same

Types of Wind Systems

Once energy needs and available wind have been estimated, a wind system can be chosen.

The four basic types of systems are

- a) Used for water pumping only.
- b) Used for heating only.
- c) Independent electrical supply.
- d) Connected to grid to balance supply and demand.

The last two systems are of most interest to the homeowner who wants to produce electricity for appliances. Hot water or space heating may also be practical for some people.

Major Components of a Wind System

The major components of an electricity-generating wind system are the turbine, generator and tower. In addition, some systems require storage (batteries or connection to grid) and/or an inverter.

Turbines

The turbine basically consists of the rotors and the shaft. A number of turbine types are available as shown in the section "Power From The Wind". Most small scale users choose a horizontal axis propeller rotor type because they are efficient and reliable.

A turbine is a sophisticated piece of equipment and usually should be bought from a reputable manufacturer, rather than built at home.

Generator

In the generator, the shaft rotating in a magnetic field produces an electric current. The current can be either alternating (AC) or direct (DC), depending on how the magnets are arranged. An alternator is simply a generator that produces alternating current.

Since the windspeed is variable, the output is also variable (except in certain special turbines) and cannot be used directly in most appliances. It must go through batteries or some other storage system first.



Storage

A system is required to take the variable output from the turbine/generator, store it, and make it available at a constant rate. The usual choices are batteries or connection to the grid.

With an independent electrical system remote from Utility lines, deep-cycle or deep-discharge batteries are the usual choice. They can be frequently discharged and recharged. Ordinary car batteries wear out if they are completely discharged a number of times.

Batteries are available in 2-volt cells. They can be connected in various ways to provide the required voltage and capacity.

Long-life batteries are in common use for forklifts, golf carts, microwave sites, and other remote applications. They may be obtained from battery suppliers, listed in the yellow pages of the telephone book. Renewable energy companies often supply batteries.

Energy can also be "stored" using the Utility. Systems connected to the utility lines are called grid-connected systems. They are usually cheaper and simpler than battery systems. During periods of high winds, excess power is sold to the Utility. When winds are low, power is drawn from the grid.

Such systems must be approved by Newfoundland Light and Power or Newfoundland and Labrador Hydro. A device is required to prevent the wind system from putting power into the lines when the lines are dead (during a power outage). This device protects workers repairing the lines.

If the system is not being used to run appliances, the energy can also be stored as heat, in a tank of hot water, for example.



An Enertech wind turbine supplies power to this Aguathuna home.

Inverters

If a battery storage system is used, the power is stored in DC. If an AC appliance is used, an inverter is necessary to convert the DC to AC. Because an inverter is expensive, not as readily available as batteries and may itself use up to 30% of the power it is inverting, it is often preferable to use as many DC appliances as possible.

Wind turbine manufacturers can often recommend suppliers of inverters, and they are also advertised in alternative energy newspapers and magazines.

Tower

A tower is a major part of any wind system. It can cost as much as the turbine/generator unit itself.

The higher the tower, the higher the windspeed, and the greater the output. However, high towers cost more and are more difficult to erect and to support.

The two basic types of tower are single pole (wood or steel) and steel frame. They may be guyed or self-supporting. A single pole with the guywires left just a bit slack usually will produce less vibration and noise than a rigid frame.

Manufacturers will usually specify a particular tower to be used with their equipment.

Economics

The big question, of course, is whether or not a wind system is worth the price. There are benefits which cannot easily be counted in dollars; wind systems do not produce radioactive wastes, acid rain, or unhealthy smoke, and are independent of power companies. But what about the dollars and cents?

Costs

The costs of a home wind system can range from several thousand dollars, if the owner does much of the work, to over \$50 000 for a large machine with new, ready-made components. The table gives a rough idea of costs for different sizes of systems. (All these costs can vary considerably.)

Small System

Item

Turbine/generator	500W	\$1 500
Tower (installed)	15m	\$1 000
Batteries		
(12 V system)		\$1 000
Inverter	400W	\$1 000
Miscellaneous		
(wires, etc.)		\$ 500
Total		\$5 000

Large System

Item

Turbine/generator	5 000W	\$ 7 000
Tower (installed)	25m	\$ 4 000
Batteries		
(120 V system)		\$ 8 500
Inverter	1 000W	\$ 2 000
Miscellaneous		
(wires, etc.)		\$ 3 000
Total		\$24 500

The following examples show how the payback periods can vary from 5 to over 100 years.



A wind system on an exposed coastal site like this will generate more energy than the same system in a calmer location, and savings will be higher.



Savings

Savings depend on how much the electricity would cost without a wind turbine and on how much energy is produced. This in turn depends on the wind and on the rotor area.

Payback Period

The payback period is calculated as a guide to whether or not an investment is worthwhile. It indicates how long it takes for the savings to pay back the initial cost.

$$\text{Payback period} = \frac{\text{Initial Cost}}{\text{Savings per year}}$$

This quick analysis shows that if the alternative is cheap and/or if the site is not very windy, the payback period on initial costs is very long.

You might still like to build a wind system for the challenge, for independence, or for pollution-free power, but you will not save money in those cases.

But if the site is windy, and/or if the alternatives are expensive, it may take only a short time to save enough to make up the initial cost of a wind system. In addition, it will provide many years of reliable service.

Safety

With any mechanical/electrical equipment, safety is very important. Wind systems have several unique safety problems.

High Winds

All parts of the system must be able to withstand very high winds. A number of AES stations in Newfoundland and Labrador have recorded gusts of over 160 km/h (86 knots), and St. John's Airport has experienced a gust of nearly 200 km/h (over 100 knots). Higher gusts than these may well occur in the future, or at heights above the 10 m of the station instruments.

Icing

Research is being done to find materials and shapes of rotors to lessen this problem. Some rotating parts can be treated to prevent ice buildup.

Moist, Salt Air

Wooden rotors in coastal areas can wear rapidly and become unbalanced. Coatings of a material such as epoxy may help. If extra coatings are applied, be sure the other parts of the unit can take the stresses caused by extra weight.

Rotors Flying Off

Different models are designed for different maximum windspeeds but all should have some method of preventing damage as winds increase.

Some models have vents that will turn out of the wind as pressure increases. Many small systems need to be shut down manually at extreme windspeeds.

Towers Blowing Over

The tower must be properly erected to withstand the strongest winds it will encounter. High stresses on the tower result from the rotation of the rotors and from the wind. Local regulations will specify required clearance around towers. Clearance equal to the height of the tower is a good rule of thumb.

Lightning

Lightning protection directly on a wind turbine is essential.

Wiring

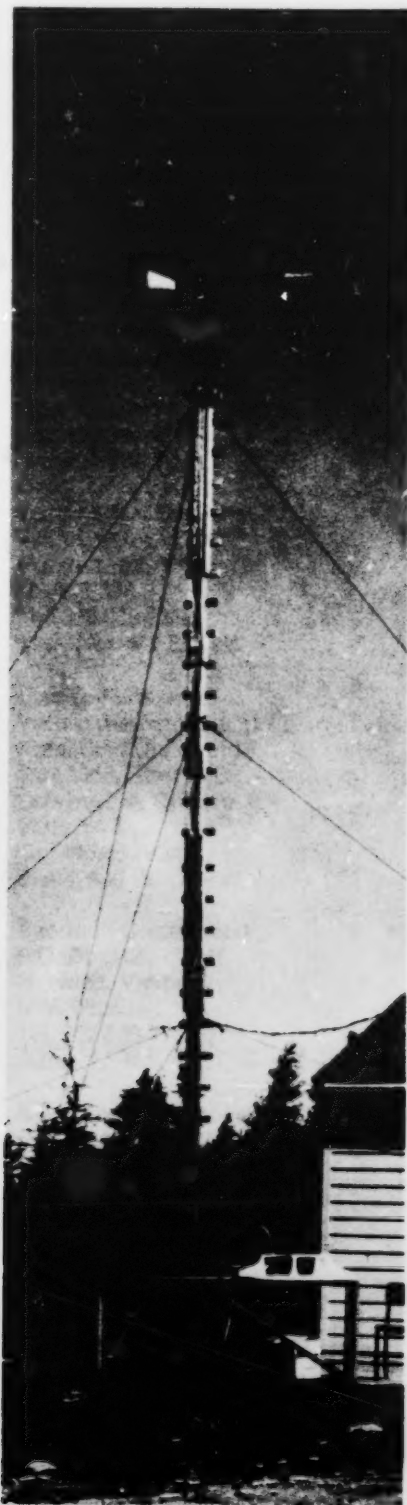
Wiring must be of good quality and properly installed by an experienced electrician.

Summary

Harnessing windpower can be a complicated business, but it has its rewards. Once a system is set up and running properly it can provide many years of free, reliable energy.

On some sites, the disadvantages of high initial costs and startup problems are offset by the advantage of an independent system providing pollution-free energy at a low operating cost.

Example Projects



**Project Name: Wind Generated Electricity
(Independent electrical supply)
St. John's, Newfoundland**

Description: A wind generator, nominally rated at 450 watts at a windspeed of 11.1 m/s, has been installed. It replaces the twice weekly recharge of a battery bank at a local service station. The batteries supply 12 volts DC to the residence. The generator is mounted on a homemade pole on the owner's property. Much of the work was done by the owner.

Costs: (1984) Capital and installation \$4 725

Savings: The generator will completely replace the need to have the battery bank recharged. This is a saving of \$500 per year.

Payback period = $\frac{\$4\,725}{\$500} = 9.5$ yrs.

The actual amount of energy generated by the wind system is 600 kWh/year, worth about \$40/year at current utility rates.

**Project Name: Wind Generated Electricity
(Grid-Connected)
Port-au-Port Peninsula, Newfoundland**

Description: A wind generator with a nominal capacity of 1 800 watts at a wind-speed of 10.7 m/s has been installed. The generator produces electricity at 120 V AC and is wired in parallel with the local electric utility. This means that the utility will supply electricity when winds are low. Conversely any surplus electricity from the wind system can be sold to the utility.

Costs: (1984) Capital and installation \$8 500

Savings: The residence consumes approximately 25 000 kWh hrs annually. The estimated wind generator output is 1 800 kWh. This result is a saving of about \$100 per year.

Payback period = $\frac{\$8\,500}{\$100} = 85$ yrs.

The energy output from the turbine is considerably less than expected, and further investigation is ongoing. Improved output could reduce the payback period substantially.

This small wind system has supplied power for lights, small appliances and a well pump to a home near St. John's for several years.

References

There are many excellent references on wind energy. The books and government publications listed below are available from the library of the provincial Department of Mines and Energy. The periodicals may be obtained through libraries.

Books

California Office of Appropriate Technology, *Common Sense Wind Energy*, Brick House Publishing Company, Andover, Massachusetts.

Clegg, Peter, *New Low Cost Sources of Energy for the Home*, Garden Way Publishing, Charlotte, Vermont (1975).

Energy Probe, *New Sources for Today*, Tutor Press, Toronto, Ontario (1978).

Gipe, Paul, *Wind Energy: How To Use It*, Stackpole Books, Harrisburg, Pa. (1983).

Hornby, Ian *The Wind Book*, Pollution Probe, 53 Queen Street, Ottawa, Ontario (1975).

Park, Jack, *The Wind Power Book*, Harrowsmith Magazine, Camden East, Ontario (1981).

Paul, Terrance, *How to Design an Independent Power System*, BEST Energy Systems for Tomorrow, Inc., Necedah, Wisconsin (1981).

Marier, Donald, *Windpower: For the Homeowner*, Alternative Sources of Energy, Inc., Milaca, Minnesota, 56353.

Stoner, C.H., *Producing Your Own Power*, Rodale Press Inc., Emmaus, Pa. (1974).

Wind Energy Report (Periodical), P.O. Box 64, Rockville Centre, New York 11571.

Government Publications

An Introduction to Wind Power, Alberta Agriculture, Farm Business Management Branch, Economic Service Division, Box 2000, Olds, Alberta T0M 1P0.

McCallum, B., *Environmentally Appropriate Technology*, Fisheries and Environment Canada (1977).

McCutcheon, S., *Exploring Energy I: Wind Energy*, Energy, Mines and Resources Canada (1981).

Wind Power, Nova Scotia Department of Mines and Energy, 1979.

Periodicals

Harrowsmith

Mother Earth News

Popular Science

Renewable Energy News

SOL/Sun

Wind Digest

Other

Ontario Ministry of Energy

California Energy Commission
1516 Ninth Street
Sacramento, California
USA 95814

Visual Material

National Film Board of Canada.

Provincial Department of Mines and Energy.

Suppliers

Listed below are names and addresses of manufacturers of small wind generators with their size ranges. Many also supply, or can recommend, other equipment, eg towers, inverters, and batteries.

Alpha Wind Energy Corp.
P.O. Box 187
Hackensack, NJ
USA 07602
Tel: 201-488-4446
Tlx: 3762485 (ALPHANJ1)
Sizes: 20 kW, 40 kW

Bergey Windpower Co., Ltd.
2001 Priesly Ave.
Norman, OK
USA 73069
Tel: 405-364-4212
Sizes: 1 kW, 10 kW

Carter Wind Systems, Inc.
Route 1, Box 405A
Burkburnett, TX
USA 76354
Tel: 812-569-2238
Sizes: 25 kW, 225 kW

Electro-Swiss
Future Resources and Energy Ltd.
(Canadian Distributor)
Box 1358, Station B
Downsview, Ontario
M3H 5W3
Tel: 416-630-8343
Sizes: 500 W - 10 kW

Enertech Corporation
P.O. Box 420
Norwich, Vermont
USA 05055
Tel: 802-649-1145
Sizes: 1.5 kW, 4 kW, 40 kW

ESI (Energy Sciences Inc.)
6524 Creek Bank Court
San Jose, CA
USA 95120
Tel: 408-268-2514
Sizes: 50 kW, 80 kW, 250 kW

Extrawatt Inc.
220 rue Principale - C.P. 15
B.P. Hamel, St. Jean de la Lande
Beauce-Sud, Quebec
G0M 1E0
Tel: 418-228-5999
Sizes: 15 kW, 30 kW

Golden State Windpower
4489 Mission Street
San Francisco, CA
USA 94112
Tel: 414-587-1884
Sizes: 50 kW

Jacobs Wind Electric Co.
2720 Fernbrook Lane
Minneapolis, Minnesota
USA 55441
Tel: 612-559-9361
Sizes: 10 kW, 15 kW

Independent Power Systems
12340 Tyler Foote Road
Nevada City, CA
USA 95959
Tel: 916-292-3754

L & R Broadcast Services Ltd.
P.O. Box 880, 514 Chartwell Road
Oakville, Ontario
Tel: 416-842-1492
Sizes: 3 kW

Sencenbaugh Wind Electric
P.O. Box 1174
Palo Alto, CA
USA 94306
Tel: 415-1593
Sizes: 500 W, 1 kW

Terra Nova Marine
P.O. Box 7096
St. John's, Nfld.
A1E 3Y3
Tel: 579-9925
Sizes: 50 W - 25 kW

Whirlwind Power Company
207½ E. Superior Street
Duluth, Minnesota
USA 55802
Tel: 218-722-1492
Sizes: 2 kW, 4 kW

Winco
c/o Dyna Technology Inc.
7850 Metro Parkway
Minneapolis, MN
USA 55420
Tel: 612-853-8400
Tlx: 290753
Sizes: 200 W, 450 W

Windpower Corp.
660 J Street, Suite 350
Sacramento, CA
USA 95814
Tel: 916-443-0511
Sizes: 100 kW, 150 kW,
200 kW, 500 kW

Windtech
P.O. Box 837
Glastonbury, CT
USA 06033
Tel: 203-659-3786
Sizes: 20 kW, 50 kW, 75 kW

Typical Household Appliance Loads

(adapted from Newfoundland Light and Power, "What's Watt")

	Typical Connected Load (Watts)	Average Monthly Kilowatt Hour (kWh) consumption
Kitchen		
Dishwasher	1 200	40
Fan	75	8
Range	12 000	100
Coffee Percolator	300	3
Fry Pan	1 150	3
Kettle	1 500	11
Mixer	150	1
Toaster	1 000	3
Refrigerator — Manual Defrost	400	60
Refrigerator-Freezer — Frost-free	900	135
Chest Freezer	340	119
Laundry		
Wringer Washer	250	4
Automatic Washer	350	5
Iron	1 000	4
Dryer	5 600	90
Water Heater — Standard 30-Gallon	2 000	480
Water Heater — Cascade 40	3 000	540
Water Heater — Cascade 60	4 500	610
Comfort and Health		
Double Blanket	180	10
Supplementary Heater	1 000	50
Heating Pad	65	1
Hair Dryer	700	6
Entertainment		
Stereo	150	11
Radio	50	4
Colour Television	400	60
Black & White Television	200	30
Outdoors		
Car Block Heater	400	96
Car Warmer	750	135
Lawnmower	1 000	10
Other		
Clock	4	3
Furnace Blower	250	50
100 watt Lamp	100	9
Sewing Machine	100	1
Vacuum Cleaner	500	3
Water Pump	250	23
Well Pump	450	20